GENERALIZED DESCRIPTION OF ENGINEERING PROPERTIES OF MAP UNITS

(Solid underlining indicates conditions that may be critical to planning, design, and construction of engineering works)

MAP UNIT[1]	GENERAL DESCRIPTION	TOPOGRAPHIC FORM	WEATHERING AND SOIL DEVELOPMENT	WORKABILITY	SLOPE STABILITY AND FOUNDATION CONDITIONS	DRY DENSITY[2] MOISTURE CONTENT AND UNIFIED SOIL CLASSIFICATION[3]	REMARKS
Artificial fill Qaf	Composition varies from place to place. Consists largely of Merritt sand along shore of Alameda. Most highway fills composed of mixtures of rock and soil derived from nearby cuts or borrow areas. Some fills contain concrete, bricks, and miscellaneous refuse. Only large fill areas shown on map; innumerable fills too small to show on map have been made for highways, streets, and building pads.	Flat, level areas a few feet above sea level along the edge of the bay; flat expanses in valley bottoms; also terraces and ramps for highways.	None in most places.	Depends on composition; varies from place to place.	Depend on composition. Properly engineered fill placed over bay mud generally suitable for light structures. Fill over bay mud may settle differentially as bay mud compacts under load.	Vary with composition. 106 (hydraulic sand fill); 23%; (14: 92-119; 18-37%)	Properly engineered fill generally suitable for use as foundation for light structures; fill overlying bay mud is susceptible to movement under earthquake stress.
Bay mud Qbm	Silt, clayey to sandy, with small lenses of sand; contains shells and organic material which in some places forms thin peaty layers. Olive-gray, massive, structureless. Soft and fluid at top, increasingly consolidated with depth. Plastic. Swells when wetted, shrinks and cracks upon drying. Maximum known thickness in this area 85 feet. Two consolidation tests of mud exposed near Derby Street, which may be older bay mud now above sea level, showed compression of 14% and 17%.	Slopes gently from landward edge toward center of bay; covers much of bottom of San Francisco Bay; forms tidal flats; much now covered by artificial fill.	None in most places.	Can be moved with hand tools; trucks and other heavy equipment may become mired in mud if excavation with such equipment is attempted.	Must be supported in most cuts. May settle differentially under load. Sensitivity generally low, but use of very heavy equipment to place fill may cause remolding and loss of strength. When used as fill upper part may swell when wet and shrink when dry.	81; 51% (22: 46-106; 20-125%) Pt; CL-CH	Can be used as fill if properly compacted but may be difficult to place because of high moisture content. Earthquake stability poor (Duke, 1958; Gilbert, 1907; Lawson, 1908; Louderback, 1942).
Alluvium and colluvium Qac	Composition varies from place to place. In small, swift-flowing streams, recent alluvium largely sand, pebbles, and boulders; alluvium in flat valleys and colluvium on hillsides generally finer material, usually dark in color. Alluvium and colluvium underlain by rocks of Contra Costa Group and (or) Moraga Formation commonly contain much swelling clay. Colluvium as much as 60 feet in thickness on west side of Moraga Valley; alluvium a few inches to more than 75 feet in thickness.	Recent alluvium fills stream valleys and forms flat valley bottoms; alluvium fills and obscures many old hillside ravines too small or indistinct to show on map; colluvium mantles sides of hills.	Thickness of soil varies from a few inches to several feet. In flat valleys soil as much as 3 feet in thickness has developed on alluvium. In places soil clayey, shrinks and swells.	Can be moved with hand tools. Where material is clayey, may be very heavy and sticky when wet, sticking to tools and miring heavy equipment.	Depend on composition. Alluvium and colluvium derived from rocks of Contra Costa Group and(or) Moraga Formation generally contain expansive clay. May cause heaving and cracking of structures in flat areas; susceptible to sliding on hillsides. Alluvium in old ravines may slide in cuts.	100; 23%; (66: 86-122; 8-34%) GW-OH	Dry density, moisture content, and unified soil classification determined on sandy and silty clay derived from Moraga Formation and Contra Costa Group.
Quaternary deposits, undifferentiated Qu	Composition and physical properties vary. Probably includes covered or unrecognized San Antonio Formation and unnamed gravel, sand and clay (Qg), as well as Temescal Formation, bay mud, Recent alluvium and colluvium, and artificial fill. Symbols for Qtc, Qts, and Qtb shown in parentheses where their existence is known (see Temescal Formation).	Primarily in valleys and on gentle slopes between San Francisco Bay and the Berkeley Hills.	Soil may be as much as 3 feet thick. In places soil clayey, shrinks and swells; may cause damage to buildings.	Can be moved with hand or power tools.	Depend on composition; generally good. Slides have formed where colluvium apparently derived from gabbro.	Vary with composition.	Includes in Temescal Formation in Oakland West quadrangle (Radbruch, 1957).
Temescal Formation Qtc (Qts, Qtb)	As used by Lawson (1914) comprises several presumably contemporaneous alluvial units of different origin, lithology, and physical properties. Qtc, dark alluvium filling channels in the eroded San Antonio Formation; consists of irregularly bedded clay, silt, sand, and gravel with organic material and some Claremont chert; dark-yellowish-brown to olive-gray. Poorly consolidated; one consolidation test on Peralta Creek showed compression of 16%; 3-18 feet thick. Qts, material apparently derived from erosion of the San Antonio Formation; consists of lenses of clay, silt, sand, and gravel with Claremont chert; yellowish brown; in places lithologically indistinguishable from San Antonio Formation; origin assumed from topographic form and lower compressive strength as indicated by one consolidation test on Sausal Creek (compression 12%). Qtb, alluvium not derived from the San Antonio Formation, probably deposited simultaneously with Qtc and Qts by streams flowing from the Berkeley Hills; consists of well-consolidated gravel-sand-silt-clay mixtures with firm pebbles and little or no Claremont chert; moderate yellowish-brown; well exposed on Arroyo Viejo where a consolidation test showed a compression of 6%, and on 73rd Street, where it has been tilted to an angle of 72°.	In flat valley bottoms and gentle slopes between San Francisco Bay and the Berkeley Hills.	In places a soil as much as 3 feet in thickness has formed on the Temescal Formation; soil clayey, shrinks and swells with seasonal moisture changes.	May be moved with hand tools. Clay beds may be sticky when wet.	Slope stability and foundation conditions fair to poor. Some minor slumping in steep cuts. Qtc generally softer than underlying and adjacent material; building founded part on Temescal channel material and part on older material may be damaged by differential settlement.	86(Qtc); 42%; (3: 73-104; 25-71%); 100 (Qts); 23% 110 (Qtb); 14%; (39: 92-133; 3-22%); Qtc, GC-OH; Qts, GC-CH; Qtb, GM-CH	Qtc does not uniformly underlie area shown as Qtc on map, but within this area fills old channels of uncertain location which meander across terraces cut in underlying material. Qts and Qtb are not mapped separately, but are included in Quaternary deposits, undifferentiated, as their boundaries are too uncertain and the lithology of the Qts too similar to the San Antonio Formation to differentiate them accurately. Their symbols are shown in parentheses where their existence is known.
Merritt Sand Qm	Sand, fine-grained, silty, clayey, with lenses of sandy clay and clay. Well-sorted. Contains small amount of organic material. Yellowish-brown to dark-yellowish-orange. No bedding observed. Slightly coherent, in most places consolidation increases at depth. Maximum known thickness 65 feet.	Forms low, rounded mound on which Alameda is built.	Very little weathering discernible; top few inches may contain small amount of organic material.	Can be moved with hand or power tools.	Must be supported in cuts; most will slump to natural angle of repose of loose sand when dry. Good foundation material.	107; 14% (14: 100-115; 4-21%) SP-SC	Merritt Sand dredged from the bay is one of the main sources of artificial fill.
San Antonio Formation (upper member) Qsu	Clay, silt, sand, and gravel. Some pebbles soft, most firm. Most beds contain flakes and pebbles of white Claremont chert, some gravel almost entirely chert. Contains montmorillonite clay. Pale-yellowish-brown to grayish-orange. Consolidation varies, some layers loose, unconsolidated. Three consolidation tests on clay layers showed compression of 4 to 6%. Maximum thickness unknown. May include some Temescal Formation and lower member (Qsl) where exposures too poor to differentiate units.	Primarily in rather steep dissected hilly areas between San Francisco Bay and steep front of Berkeley Hills.	Soil as much as 3 feet thick has formed on formation in places. Soil clayey, swells and shrinks with seasonal moisture changes and may cause damage to buildings; may creep on slopes.	Can be moved with hand tools.	Large slides have formed in this unit; montmorillonite clay, interbedded poorly consolidated sand and clay, steep slopes, and ground water probably contributing factors. Generally suitable foundation material for light structures where slopes are not steep.	105; 18% (77: 91-123; 8-30%) GM-CH	Probably minor.
San Antonio Formation (lower member) Qsl	Gravel, weathered, dense, with silty clay matrix. Some firm pebbles, most soft; breaks across pebbles when struck with pick. Unit very uniform in lithology, contains a few slightly silty, pebbly clay lenses. Contains little or no Claremont chert. Contains montmorillonite clay. Light-brown to grayish-orange. Two consolidation tests showed compression of 5 and 7%. Maximum thickness unknown.	In steep to moderately sloping hilly areas between San Francisco Bay and the steep front of the Berkeley Hills.	Most pebbles of formation soft, probably weathered in place. Soil as much as 3 feet thick in places. Depth of weathering unknown. Soil clayey, shrinks and swells.	Can be moved with hand or power tools.	Generally stable in 1:1 cuts; some slumping on steep slopes.	114; 16% (25: 106-123; 10-21%) GC	
Unnamed gravel, sand, and clay Qg	Gravel, sand, silt, and clay; olive-gray, dark-yellowish-orange, light-brown. Contains swelling clay; expands when wet, shrinks and cracks when dry. Overlies Leona Rhyolite, contains pebbles of rhyolite. Bedding poorly defined both laterally and vertically; average thickness of beds about 30 feet. Tilted and contorted. Contains molluscs of possible early Pleistocene (Irvingtonian) age. Maximum thickness unknown.	Small ridge within Hayward fault zone and minor rounded hills nearby.	Unit appears to be weathered to depth of maximum exposure--50 feet. Weathered rock soft, clayey, joints iron-stained. Soil clayey, 1-3, feet thick.	Can be moved with hand tools or power equipment.	Slope stability poor; slides abundant. Slides have formed in clayey layers of this unit on slopes as gentle as 2:1. Foundation conditions unknown, probably fair. Swelling of expansive clay could cause damage to structures.	103 (sandy and silty clay with some gravel); 21% (65: 75-125; 11-44%) GC-CH	Earthquakes may trigger landslides in this unit.
Leona Rhyolite and Northbrae Rhyolite Tl and Tn	Rhyolite, some porphyritic. Fresh rock light-gray to greenish- or light-bluish-gray; weathers white, dark-yellowish-orange, reddish-orange. Contains pyrite in many places. Includes a small amount of glass. Altered, sheared, and fractured. Much of Leona Rhyolite apparently intrusive; in places intrudes overlying Knoxville Shale which is now baked and contorted at contact. Some Northbrae Rhyolite distinctly flow-banded. May include small amounts of Franciscan and Knoxville sandstone and shale. Maximum thickness unknown.	Forms knobs, crags, and steep knobby dissected hills.	Weathering as much as 30 feet deep; highly weathered rock consists of loose fragments in clay matrix. Soil lacking or less than 18 inches thick; in ravines may be more than 12 feet thick.	Can generally be moved with power equipment; in some places requires blasting.	Slope stability and foundation conditions good. Debris slides observed locally where rock excessively fractured and weathered.	162(s); 0.1%; 99 (weathered); 20% (3: 98-102; 9-27%) (Leona Rhyolite)	Crushed Leona Rhyolite is major source of fill and base rock; pyrite formerly mined for sulfur; runoff from rhyolite hills very acid; corrodes concrete sewer pipe. Some slopes so steep that development may be difficult.
Contra Costa Group, undifferentiated Tcc (Includes Pinole Tuff, Tcp)	Conglomerate, sandstone, and siltstone, with minor amounts of limestone and tuff, interbedded and lenticular. Greenish-gray, reddish-brown. Contains unnamed rocks younger than formations of the Contra Costa Group (Bald Peak, Siesta, Moraga, and Orinda) which are recognized west of Moraga fault. Includes Pinole Tuff, Tcp. Rocks poorly consolidated, contain montmorillonite clay. Fractured, cut by faults; prominent and widespread jointing; joint surfaces iron-stained. Beds range from less than 1 inch to 80 feet thick. Maximum thickness of unit unknown.	Underlies rolling to moderately steep-sided hills and intervening northwest-trending valleys.	Weathering irregular, from a few inches to several feet. Weathered rock soft, clayey. Soil lacking or as much as 10 feet thick in ravines; generally clayey.	Can be moved with power equipment.	Slope stability poor. Abundant slides in both soil and rock, on natural and cut slopes. Slides abundant on north-facing slopes; slides in rock may move on joint surfaces (Radbruch, 1963). Expansion of clayey soil derived from this unit may cause heaving of structures.	131(s)(ss); 2.1%; 143(s) (siltstone), 4.6%; 108 (cgl., ss, siltstone, weathered?); 15%; (7: 96-123; 7-23%)	Properly compacted material from formation suitable for artificial fill. Earthquakes may trigger soilslips and landslides in this unit, particularly if rocks and soil are saturated. Abundant landslides may increase cost of development.
Bald Peak Formation Tbp	Basalt with minor amounts of sedimentary rocks. Large plagioclase phenocrysts abundant. Fresh basalt dark-gray, weathers yellowish-gray. Typically cut by many intersecting fractures along which alteration has taken place, so that in any exposure rock commonly consists of dark, hard, subangular blocks 1 inch to 1 foot across, in a matrix of soft, light-colored material, predominantly clay with some silt-sized mineral grains. Sedimentary layers include varicolored conglomerate, sandstone, and siltstone containing abundant volcanic lithic fragments. Maximum thickness unknown. Conformably overlies Siesta Formation.	Forms moderately steep hillsides and caps small ridges.	Alteration with much softening along fractures in rock observed wherever exposed; soil sparse, generally only 2 or 3 inches thick.	Can generally be moved with power equipment because of intensive fracturing and alteration.	Slope stability and foundation conditions good. Small blocks of unaltered material fall out of weathered matrix and accumulate at base of cuts.	Not determined.	
Siesta Formation Ts	Claystone, silty, and sandstone, very fine to medium-grained; greenish-gray to pale-brown. Claystone generally massive, may be very finely laminated. Minor pebbly conglomerate, cherty limestone, impure tuff, and basalt. Cut by faults. Beds 1 inch to 12 feet thick; most 1-5 feet thick. Maximum thickness unknown. Conformably overlies the Moraga Formation.	Flat or gently rolling topography of bottom and sides of Siesta Valley.	Weathering irregular, depth varies from a few inches to as much as 15 feet. Weathered rock soft, structureless, clayey. Soil lacking or as much as 3 feet thick, more in ravines.	Can be moved with hand tools or power equipment.	Many slides form on both natural and cut slopes in this unit, although some highway cuts appear to be stable at 1:1 slopes. Foundation conditions fair to poor. Expansion of clayey soil may cause damage to structures.	150(s)(siltstone): 1.2%; 116 (weathered siltstone): 17%.	Part of floor of Siesta Valley north of Highway 24 consists of old slide material of the Siesta Formation.
Moraga Formation Tm	Basalt and andesite flows, dark-gray· locally amygdaloidal. Interbedded clastic rocks, includes conglomerate, sandstone, siltstone, agglomerate, tuff, mixtures of volcanic and nonvolcanic debris; minor limestone and lignite. Layers a few inches to 200 feet thick. Yellowish-gray rhyolite tuff within clastic sequence forms marker bed near middle of formation. Poorly sorted volcanic debris on hill south of Moraga substation may be volcanic mudflow. Entire formation sheared and fractured. Maximum estimated thickness approximately 1,300 feet. Conformably overlies and probably interfingers with Orinda Formation.	Forms prominent, steep-sided ridges. Slopes generally more than 30°.	Tops of individual flows oxidized red; soil sparse, where developed is generally clayey. Colluvium may be as much as 60 feet thick.	Clastic rocks or intensely fractured volcanic rocks can be moved with power equipment; basalt and andesite generally require blasting.	Basalt and andesite generally stable, and foundation conditions good. Many small slides form in clastic rocks, and in places very large slides have moved on clayey clastic units or formed in overlying clayey colluvium.	168(s)(basalt); 0.5%.	Crushed volcanic rock from the Moraga Formation is a major source of fill and base rock in this area; some large firm blocks of unweathered volcanic rock also used as riprap. Slopes so steep that development may be difficult.
Orinda Formation Tor	Conglomerate, sandstone, siltstone, and claystone; contains swelling clay. Bluish-gray, greenish-gray and grayish-red. Beds 1 inch to 100 feet thick. Sheared and fractured, numerous joints. Beds lenticular. Contains minor diabase dikes. Maximum estimated thickness approximately 2,300 feet. In the Berkeley Hills overlies the Claremont Shale with apparent erosional and possibly slight angular unconformity.	Generally forms valleys, but harder rocks of formation in places form steep ridges.	Depth of weathering irregular; varies from 3 to 20 feet; weathered rock soft, clayey. Soil sparse; may be lacking or as much as 3 feet thick, more in hillside ravines.	Can generally be moved with power equipment, but some dense, hard sandstone or conglomerate lenses may require blasting.	Slope stability poor; many slides in both rock and soil on both natural and cut slopes. Soil slides on natural slopes of 25° and steeper; some cuts appear stable at 1:1. Swelling of expansive clay in rock and overlying soil could cause damage to structures.	143(s)(ss); 1.3%; 140(ss, sh, and cgl.); 7%; (7: 134-150; 5-14%)	Sandstone or conglomerate beds that require blasting for removal may disintegrate in cuts after exposure to air. May squeeze in tunnels.
San Pablo Formation Tsp	Sandstone, soft, medium-grained, slightly clayey, with shell bands in places; few lime-cemented resistant layers 1 foot or less in thickness. Minor pebble conglomerate, locally fossiliferous. Some layers of clay shale, with jarosite coatings on joint surfaces. Fresh rock olive-gray, weathered rock dark yellowish orange. Beds from a few inches to tens of feet in thickness. Joints less than one inch to several feet apart. Maximum thickness unknown. Rests unconformably on the Briones Sandstone. (Pease, 1953, p. 48).	Moderately steep, rounded hills and ridges.	Rock weathered, soft, iron-stained along joints to depths of 20 feet or more. Soil generally sparse sandy loam, less than 1 foot thick; may be 6 feet or more in thickness in ravines.	Can be moved with power equipment.	Stands in 1:1 cuts with only minor sloughing. Foundation conditions good.	121(s)(ss); 1.5%	
Briones Sandstone Tb (includes Hercules shale member of Lawson, Thl)	Sandstone, slightly clayey, fine-grained, some sandy silty claystone. Light yellowish-gray when fresh; weathers dark yellowish orange. Joints a few inches to less than an inch apart; breaks into small pieces along joints. Lower part of formation generally massive, contains resistant fossiliferous beds; upper part softer, contains more claystone. Upper and lower parts not separated on map. Hercules shale member (Thl) predominantly siliceous. Thickness approximately 1,300 feet (Sheehan, 1956). Conformably overlies and grades into the Rodeo Shale.	Generally forms ridges or rolling hills with steep-sided ravines. Ridge slopes commonly steep, 25-30°.	Weathered rock soft to moderately hard; intensely weathered to 20 feet, iron-stained to depths of at least 75 feet maximum depth observed. Soil generally sparse.	Can be moved with power tools; clayey sandstone and claystone may be sticky when wet.	Minor erosion and gullying in soft weathered sandstone in cuts; soil and weathered rock slides observed in places in upper part of formation on natural slopes as low as 20°. Foundation conditions good to fair.	102; 20% (22: 91-114; 11-28%).	
Rodeo Shale[4] Tr	Clay shale, siliceous shale, siltstone, some fine clayey sandstone. Much massive, bedding irregular, obscure in most places. Olive-black where fresh; weathers pale yellowish brown to grayish orange. Intensely jointed; joints less than an inch to 1 foot apart. Fissile. Contains gypsum and/or jarosite in some places. Maximum thickness about 700 feet. Contact with the Hambre Sandstone is conformable and commonly gradational. (Pease, 1953).	Steep-sided hills; slopes of 30° or more common.	Weathered, iron-stained along joints to depths of 60 feet or more. Soil sparse, dusky yellowish brown, generally less than 1 foot thick. Bare slopes common.	Can be moved with power tools.	Stands well in most places in cuts of 1:1. Some slides and slumping in clayey parts of unit and overlying soil when wet. Foundation conditions good to fair.	97; 23% (4: 87-105; 20-25%)	
Hambre Sandstone[4, 5] Th	Sandstone, very fine-grained, clayey, soft, pebbly in places, with minor amounts of clayey siltstone. Some firm sandstone beds 2-10 feet thick. Light olive-gray; grayish-orange when weathered. Numerous closely spaced joints, commonly 1 to 3 inches apart. Generally very friable, sticky when wet. Weathers spheroidally between joints into small, rounded fragments. Estimated maximum thickness 3,000 feet (Pease, 1953). Conformably overlies Tice Shale.	Steep-sided hills, slopes 25-30°. Some more resistant beds form knobs, ridges, spurs.	Weathered, soft, to depths of 25-35 feet. Soil sparse on resistant sandstone; otherwise 2-5 feet thick, more in ravines. Soil brownish-black, clayey, shrinks and swells.	Most can be moved easily with power tools; some resistant beds may require blasting.	In places both soil and rock slides form on natural slopes as low as 25°. Stands in some artificial cuts of 1½:1; many show some slumping and much washing and gullying. Sandy mud accumulates at base of cuts. Foundation conditions good to poor.	102; 21% (17: 88-115; 15-33%)	See footnote 4.
Tice Shale[4] Tt	Shale, siliceous, cherty, or tuffaceous, with fine-grained argillaceous or tuffaceous sandstone and some limestone. Much shale finely laminated, beds generally less than an inch in thickness. Olive gray when fresh, weathers yellowish gray to grayish orange. Joints in shale generally less than an inch apart; shale brittle, breaks into small pieces. Many joint surfaces iron-stained, coated with yellow jarosite. Contains abundant Foraminifera, some mollusks. Maximum thickness approximately 1,100 feet; conformable with underlying Oursan Sandstone. (Sheehan, 1956).	Moderately steep-sides hills, slopes generally about 25°.	Weathered along joints to maximum depth observed; weathered rock remains hard. Soil generally olive-gray, clayey, 1-3 feet in thickness.	Can be moved with power equipment.	Stands in 1:1 cuts with minor sloughing. Soft, clayey sandstone locally may slump when wet. Foundation conditions good.	112(s); 10.9%	
Oursan Sandstone[4, 6] To	Sandstone, very fine grained, slightly clayey, soft, with some beds of more resistant sandstone and minor limestone lenses. Medium light gray to olive gray when fresh; weathers yellowish gray to yellowish brown. Predominantly massive, more resistant beds 1 to 3 feet thick. Closely spaced joints, less than an inch to 1 foot apart, iron-stained. According to Pease (1953) the formation averages about 800 feet in thickness. It is conformable with the Claremont Shale.	Steep rounded hills and steep-sided ravines. Slopes 30 degrees or less.	Spheroidal weathering common, spalls at surface. Weathered to depths of 30 feet or more. Soil generally 1-3 feet thick, more in ravines; slightly clayey, dark yellowish brown.	Easily moved with power equipment.	Stands in cuts of 3/4:1. Rocks 1 to 3 feet across and cones of small debris, i.e., fragments less than 1 inch in diameter, accumulate at base of cuts. Foundation conditions good.	146(s); 1.7%	See footnote 5.
Claremont Shale[4] Tc	Chert and shale, rhythmically bedded; also tuffaceous sandstone, siliceous shale, porcellanite, dark clay shale, and sandstone. Chert predominant in Berkeley Hills, siliceous shale and tuffaceous sandstone elsewhere. Chert bituminous in places, cut by sandstone and diabase dikes. Weathered chert white to yellowish-gray; medium-gray when fresh. Chert beds commonly 1-4 inches in thickness, interbedded shale less than 1 inch thick; brittle, fractured, and intensely contorted. Thickness difficult to determine because of extensive deformation; generally not more than a few hundred feet thick, but could possibly be more than 1,000 feet thick in the Berkeley Hills. Conformably overlies Sobrante Formation.	Chert forms very steep sided ridges in Berkeley Hills. Underlies main prominent ridge in hills. Siliceous shale underlies moderately steep slopes generally 20-25°.	Weathering to depths of more than 20 feet characterized by lightening of color, widening of fractures. Weathered rock hard. Fresh rock rarely seen at surface. Soil 2 inches to 3 feet thick.	Chert and siliceous shale can generally be moved with power equipment. Sandstone beds near base of unit in Berkeley Hills usually require blasting.	Both chert and siliceous shale stand in 1/2:1 cuts, but chert in places subject to slump and creep. Diabase dikes in Berkeley Hills generally hydrothermally altered to soft, clayey material; may carry water and may cave in tunnels (Page, 1950).	152 (chert); 2.5% (3: 150-153; 1-5%)	Slopes in chert so steep that development may be difficult in places. Gas may be encountered when tunneling through this formation (Page, 1950).
Sobrante Formation[4] Tso	Sandstone, fine- to medium-grained, at southeast end of Oursan Ridge (type locality of Lutz, 1951); outcrop area at type locality very small. Large exposures underlying Claremont Shale in Berkeley Hills and northeast of Pinole Creek consist of massive siltstone and fine-grained sandstone, interbedded; some glauconitic. Olive-gray, yellowish-brown; characteristically weathers to pale-red. Commonly coated with grayish-yellow jarosite (Briggs, 1951). Foraminifera from Berkeley Hills dated as Saucesian or Relizian. Thickness difficult to determine owing to deformation and/or poor exposures. Grades into the underlying Kirker Tuff (Pease, 1953, p. 19).	Underlies moderately steep slopes.	Weathering extensive; some weathered rock firm, most soft, iron-stained, clayey. Depth of weathering more than 10 feet where observed. Soil a few inches to 3 feet in thickness; thicker in ravines.	Can be moved with power equipment.	Generally stands in 1:1 cuts with minor sloughing; sliding in siltstone in places on natural slopes.	137 (s) (sh); 3.6%; 143 (s) (fine ss); 1.1%	
Kirker Tuff Tk	Tuff and tuffaceous sandstone in lower part, white to very light gray, weathers medium dark gray to brownish gray. Hard, very fine grained. Beds less than an inch to 8 feet thick; some beds finely laminated. Joints a few inches to 18 inches apart, prominent perpendicular to bedding. Upper part massive clayey siltstone interbedded with tuffaceous sandstone (Concord Formation of Clark, 1918). Maximum thickness shown by Pease (1953, p. 7) in a geologic column is 250 feet. Conformably overlies the San Ramon Sandstone.	In places tuff forms prominent resistant ledge or caps ridge; siltstone forms rounded hills with steep to moderate slopes (20-30°).	Tuff generally fresh, firm; iron-stained along joints. Soil sparse; consists of humus with rock fragments. Siltstone soft, weathered where observed. Soil over siltstone 1-3 feet thick, clayey.	Can be moved with power equipment.	Tuff stands with minor sloughing in 1/2:1 cuts; foundation conditions good. Siltstone slumps and creeps on hillsides, some slumping in 2:1 cuts; foundation conditions fair to poor. Slopes and cuts in siltstone generally covered with fine clayey debris.	128(s)(tuff); 5.1%; 113(s)(siltstone); 11.4%	
San Ramon Sandstone Tsr	Sandstone, tuffaceous sandstone, and tuff, interbedded; very fine grained; slightly calcareous; some sandstone conspicuously feldspathic; white and yellowish gray to greenish gray, weathers yellowish brown. Cut by iron-stained joints 1 inch to 1 foot apart. Beds 1 inch to 5 feet in thickness. Maximum thickness 250 feet (Pease, 1953, p. 16). According to Pease (1953, p. 11) "Good exposures of the contact between the Markley formation and the San Ramon formation---show no angular discordance. In fact, the contact seems to be gradational in places."	Generally forms ridges.	Weathered rock firm to soft; some weathers spheroidally, spalls into small moderately hard pieces; center of blocks remain hard. Weathered to observed depth of 6 feet. Soil generally rocky loam less than 1 ft thick.	Can be moved with power equipment.	Stands in 1:1 cuts with minor sloughing of rock fragments from face.	143(s); 5.2%	
Markley Sandstone Tsm	Sandstone, massive, with minor amounts of shale and siltstone, in northeast corner of map and adjacent areas; in anticlinal valley southwest of Oursan Ridge, predominantly clay shale, massive, olive gray, with some sandstone beds generally less than 5 feet thick near top of unit. Sandstone contains prominent bands and nodules cemented by iron oxide. Clay shale is the dominant lithologic type exposed in this map area. Pease (1953, p. 11) reports that "The Markley formation measures at least 2,000 feet thick in Sobrante anticline, and the base of the unit is not exposed."	Shale forms low, rounded hills and broad, flat valleys; natural angle of slope generally 20° or less.	Soil over shale clayey, olive gray; commonly 6 feet or more in thickness in valleys. Shrinks and swells with seasonal moisture changes. Shale soft, weathers to maximum depth observed of 6 feet.	Shale can be easily moved with power tools; becomes sticky when wet.	Slope stability poor. Numerous slides on both natural and cut slopes; shale stands in 2:1 cuts 6 feet in height with minor sloughing. Foundation conditions fair to poor.	119(s); 14.4%	Earthquakes may trigger landslides in this unit.
Unnamed Eocene sandstone and shale Tes	Massive, fine-grained sandstone; glauconitic sandstone; soft silty sandstone with organic material; siltstone; dark-colored clay shale. Fresh sandstone medium-gray, weathers yellowish-brown. Some rocks closely resemble underlying Cretaceous rocks, some are almost indistinguishable from overlying rocks. Some fine-grained rocks in places coated with yellow jarosite (Briggs, 1951). Sheared and fractured. Contains sparse molluscan fauna. Maximum thickness unknown, probably 500-1000 feet; contacts are faults or covered.	Forms moderately steep-sided ridges and valleys in Berkeley Hills.	Maximum depth of weathering unknown. Fresh rock rare at surface. Weathered rock soft. Soil and colluvium 1-3 feet thick; may be as much as 15 feet thick in ravines.	Can generally be moved with power equipment; some beds of massive sandstone may require blasting.	Slope stability and foundation conditions vary with material, but generally good unless rock is sheared and wet. In many places stands in 1:1 cuts, but may slide if wet and sheared.	108 (weathered siltstone); 17%; 143 (weathered ss); 2.4%	
Martinez Formation Tmz	Sandstone and siltstone. Sandstone medium-grained, much heavily glauconitic; greenish-yellow or moderate olive brown. Some siltstone siliceous, some clayey; light olive gray or yellowish gray when fresh, weathers grayish orange to pale red. Many fracture surfaces in siltstone coated with grayish yellow jarosite. Beds 18 inches to 30 feet thick; some siltstone massive. Numerous joints, less than an inch to 3 feet apart. Thickness unknown; believed to be conformable with underlying Cretaceous rocks (Pease, 1953, p. 8).	Forms moderately steep rounded hills and ridges; slopes generally 15-30°	Weathered to depths of 50 feet. Weathers spheroidally in many places. Weathered siltstone soft, sandstone soft to firm. Soil generally thin, rocky, except in ravines.	May be moved with power equipment.	Stands in 1:1 cuts except where sheared; some slumping and falling of rocks from face of steeper cuts. Foundations conditions good to fair.	158(s); 0.3%	
Siliceous shale* Tp	Shale, siliceous, light-gray to medium-gray, and sandstone, hard, fine-grained, yellowish-gray. Beds 10 feet to less than 1 inch thick, most 3 inches to 3 feet. Contorted, cut by numerous faults. Contains Paleocene Foraminifera. Maximum exposed thickness about 500-700 feet; upper contact faulted; appears conformable with underlying red and gray Cretaceous shales.	Exposed on steep ridges and hillsides; minor topographic determinant, as occupies very small area.	Depth of weathering more than 20 feet; weathered rock hard; unweathered material rare on surface. Soil sparse, largely rock fragments with minor organic material.	Can be moved with power equipment.	Slope stability generally good; stands in 1:1 slopes with minor sloughing. Foundation conditions unknown.	156(s) (shale); 1.9%	
Sandstone* Kr	Sandstone, fine- to medium-grained, yellowish-brown, in beds 6 inches to 12 feet thick; contains round dark concretions ("cannon balls"). Interbedded with clayey siltstone and very fine-grained sandstone, medium-gray to dusky-yellow, in beds less than 1 inch to 1 foot thick. Rocks contain abundant flakes of organic material, display crenulated bedding. Some dark shale beds. Distinctive light-olive-gray and grayish-red Late Cretaceous foraminiferal shale at top of unit. Rocks deformed, faulted, fractured. Thickness unknown, probably between 1,700 and 2,000 feet; grades into underlying shale.	Forms steep-sided ridges and canyons.	Weathered to more than 20 feet. Weathered rock generally firm, iron-stained; some soft, crumbly. Soil sparse, generally less than 1 foot thick.	Can generally be moved with power equipment; may require blasting in places.	Bulk of formation stable; stands in 1/2:1 cuts; foundation conditions good. Slides common in dark shale beds and in red and green shale at top of unit.	140(s) (ss); 2.4% (2:137-143; 1.2-3.5%)	Slopes in places so steep that development may be difficult.
Shale* Ks	Shale, massive, olive-gray; also interbedded shale and fine sandstone. Massive shale in beds 20 feet or more in thickness. Faulted and fractured. No fossils found. Thickness unknown, may be as much as 1,500 feet. Grades into underlying Oakland conglomerate.	Forms valleys in most places as soft shales of formation are easily eroded.	Weathered along joints to maximum observed depth of 20 feet. Weathered shale soft, crumbly, clayey. Soil and colluvium generally 5 feet or more in thickness.	Can generally be moved with power equipment.	Slope stability and foundation conditions appear to be good for most of unit; slides frequent on steep slopes in southeast part of outcrop area (see map).	156(s) (shale); 2.3%	
Oakland Conglomerate Ko	Conglomerate, with sandstone matrix, and sandstone, coarse- to medium-grained; minor amounts of shale. Pebbles in conglomerate commonly 1-8 inches in diameter. Many pebbles fractured. In places sandstone contains shale fragments. Yellowish-brown, weathered; fresh rock not seen on surface. Sandstone and conglomerate in lenticular beds mostly 3-10 feet thick. Sheared and fractured. Appears barren of fossils. Maximum thickness about 1,000 feet; gradational with underlying sandstone, shale, conglomerate.	Generally caps a ridge.	Thoroughly weathered to maximum observed depth of 20 feet. Weathered sandstone firm to soft, slightly clayey; conglomerate pebbles hard. Soil generally sparse or lacking.	Can generally be moved with power equipment.	Slope stability and foundation conditions good.	125(s) (weathered ss); 2.3%	
Sandstone, shale, conglomerate* Kjm	Sandstone, fine- to medium-grained; shale; minor conglomerate. In places contains fragments of organic material. Yellowish-brown in outcrop, medium- to dark-gray on fresh surfaces. Massive to thin-bedded. Beds one-quarter of an inch to 10 feet thick. Sandstone beds increase in frequency and thickness toward top of unit. Shale near base distinguished by massive character from fissile Knoxville shale, from which it is separated by East Chabot fault. Contorted, sheared, fractured; most joints iron-stained. Fossils rare. A crude approximation of the thickness of this intensely deformed unit is 2,500 feet.	Forms steep-sided ridges and canyons.	Maximum depth of weathering unknown; may be as much as 50 feet in places; weathered rock firm to soft. Soil commonly a few inches to 3 feet thick, more in ravines.	Can be moved with power equipment.	Slope stability and foundation conditions generally good to fair; minor sloughing in cuts.	150(s) (ss); 1.5% 115 (weathered ss); 12% (7: 105-122; 9-17%)	
Upper Cretaceous formations, undifferentiated Ku	Sandstone, fine- to coarse-grained, and shale. Light-gray to medium gray when fresh, weathers yellowish-brown or grayish-orange. Some massive sandstone beds, but predominantly alternating beds of sandstone and shale; without any visible distinguishing characteristics of other Cretaceous units. Sheared, fractured, and contorted. May include any of the Upper Cretaceous units and possibly unrecognized Eocene rocks. Fossils rare. Thickness and stratigraphic relations unknown.	Forms rolling hills, moderately steep-sided ridges and canyons.	Depth of weathering may be 60 feet or more; some weathered rock firm; most soft, crumbly. Soil and colluvium may be as much as 25 feet thick in ravines.	Can be moved with power equipment.	Slope stability and foundation conditions good to poor. In places stands in 1:1 cuts, but subject to both minor sloughing and major sliding. Two of largest slides in Berkeley Hills--Broadway Terrace and Drury Road slides--involve rocks of this unit.	See individual Cretaceous units.	May squeeze in tunnels where sheared.
Knoxville Formation Jk	Shale, olive-gray, fissile; sandstone, fine- to medium-grained, olive-gray; also includes pebble conglomerate in dark shale or sandstone matrix, minor concretionary limestone, and lignite. Some shale massive, some interbedded with sandstone. Shale contains abundant Buchia piochii. Thickness and stratigraphic relations unknown.	Generally in valleys, as soft shales of formation are easily eroded.	Depth of weathering irregular; may be 20 feet or more in places. Some weathered rock firm, most soft, clayey. Soil commonly 1-3 feet thick.	Can be moved with power equipment.	Slope stability and foundation conditions generally fair; minor sloughing in cuts.	160(s) (ss); 1.4%; 116 (weathered sh); 15% (3: 113-120; 13-19%)	May squeeze in tunnels where sheared.
Franciscan sandstone and shale KJfs	Sandstone (graywacke), fine- to coarse-grained, greenish-gray where fresh, yellowish-brown to yellowish-orange where weathered; and shale, olive-gray. Sandstone contains fragments of other rocks, particularly shale. Beds a few inches to 30 feet in thickness. Some sandstone massive, some in thin beds interbedded with shale. Sheared and fractured. Age of Franciscan rocks in other places ranges from Late Jurassic to Late Cretaceous (Bailey, Irwin, and Jones, 1964); age in this area unknown. Thickness and stratigraphic relations unknown.	Underlies moderately steep but generally rounded hills, and sharply dissected by steep-walled valleys.	Weathered rock firm to soft. As much as 20 feet of sand and sandy soil may be developed on this unit, especially on the soft, massive weathered sandstone in the Piedmont area.	In places can be moved with power equipment; dense, massive sandstone may require blasting.	Slope stability and foundation conditions in fresh rock good; subject to sliding where intensely sheared.	162(s) (ss); 0.5%; 119 (weathered ss); 12%; (6: 115-124; 8-15)	Franciscan sandstone has been quarried to provide rock for fill and base course in this area.
Franciscan chert and shale KJfc	Chert and shale, rhythmically bedded; generally grayish-red, yellowish-brown where weathered, some grayish-green. Cut by numerous quartz veins. Brittle, fractured, breaks into small pieces. Some chert beds as much as 5 feet thick, but more commonly one-half inch to 3 inches thick, separated by shale partings less than 1 inch in thickness. Thickness and stratigraphic relations obscure.	Forms knobs and ridges.	Weathering slight; weathered rock remains hard; maximum depth of weathering observed 12 feet; soil sparse, generally a few inches thick.	Can be moved with power equipment where fractured; may require blasting in places.	Slope stability and foundation conditions good; stands in 1:1 to 1/2:1 slopes with minor sloughing of small fragments.	162(s) (chert); 0.8%	In places has been used for fill.
Franciscan greenstone KJfg	Fine-grained igneous rock, predominantly basalt; dense, hard, tough; amygdaloidal in places. Fresh rock dark-greenish-gray; yellowish-brown, moderate-brown, grayish-brown where weathered. Cut by numerous fractures; commonly altered to soft chloritic material and highly weathered.	Underlies moderately steep hills.	Very little unweathered greenstone observed on surface; highly weathered rock consists of crumbly rock fragments in clayey matrix. Soil less than 1 foot thick.	Can be moved with power equipment.	Slope stability fair. Stands in 1½:1 to 1:1 cuts. Foundation conditions good.	171(s); 1.0% (2:162-181; 0.7-1.3%)	In places greenstone has been used for fill.
Franciscan metamorphic rock KJfm	Includes silica-carbonate rock (see explanation), low-grade schists, and semi-schists. Quartzo-feldspathic schist derived from sandstone common near Hayward fault. Abundant glaucophane schist apparently derived from and grades into siltstone, sandstone, and greenstone. Sheared, fractured, altered; many quartz veins; glaucophane coats many fracture surfaces. Color yellowish-brown, gray, light-brown; glaucophane-rich rocks grayish-blue. Includes small amounts of sandstone, greenstone, serpentine.	Generally underlies steep hillsides: silica-carbonate rock forms prominent craggy knobs.	Weathering of silica-carbonate rock slight; weathering of other metamorphic rocks varies; some very soft. Much silica-carbonate rock bare of soil; in places soil may be several feet thick.	Generally can be moved with power equipment, although some silica-carbonate rock may require blasting.	Slope stability and foundation conditions fair; generally stands in 1:1 cuts.	181(s) (glaucophane schist); 0.2%	
Serpentine sp	Pale-greenish-yellow-green, bluish-gray, black, and pale-blue serpentine, generally soft and intensely sheared. May include small amounts of Leona Rhyolite and Franciscan rocks too small to show on the map.	Underlies moderately steep, dissected hills and valleys.	Serpentine intensely sheared, surface weathering difficult to detect. Soil sparse or absent, generally less than 1 foot in thickness.	Can be moved with power equipment in most places; blasting seldom required.	Slope stability and foundation conditions fair to poor; intensely sheared serpentine may slide in slopes as low as 2:1.	159(s); 0.1%; 104 (decomposed); 18% (19:87-121; 8-30%)	May squeeze in tunnels.
Gabbro gb	Gabbro, medium-grained, greenish-gray; generally altered to mottled, pale-greenish yellow, soft material.	Generally underlies moderately steep hillsides.	Much gabbro highly altered to very soft clayey material; thick black clayey expansive soil commonly developed on gabbro.	Can be moved with power equipment in most places.	Slope stability and foundation conditions poor in many places. Much gabbro highly altered to soft, clayey material; altered gabbro and overlying clayey soil subject to creep and sliding. Slides on knoll southeast of Mills College are in dark soil probably derived from weathered gabbro.	174(s); 0.4%; 156(s) (weathered); 1.1%	

Faulting

The rocks of most of the above units have been compressed into northwest-trending folds and cut by numerous faults. These faults range from very small breaks a few inches in length with a displacement of less than an inch, to the Hayward fault zone which extends from the northwest corner to near the southeast corner of the map and for many miles farther to the south. The Hayward fault zone is here considered as the zone within which surface breakage associated with earthquakes is known to have occurred during historic time, and other movement has taken place recently enough in the geologic past that geologic and geomorphic features indicating recent movement are still clearly visible. The fault zone lies in a broad band of acute deformation which was described by Lawson (1914) in the San Francisco folio. A major fault, the Chabot fault (Robinson, 1956), which is older than the currently active Hayward fault zone and apparently inactive, lies east of the Hayward fault zone and subparallel to it, separating the Upper Cretaceous rocks to the northeast from both the older rocks and the Leona Rhyolite[7] to the southwest. The Chabot fault as well as a number of other northwest-trending faults east of the Hayward fault zone are cut by north-trending, predominantly right-lateral faults and lesser northeast-trending predominantly left-lateral faults (Case, 1963). The fractured rocks along any of these faults may form passages for ground water, and artificial cuts across them may require draining; the soft sheared rocks along the faults are also subject to landsliding.

Surface outcrops, as well as exposures in the Bay Area Rapid Transit Berkeley Hills tunnel, show that a low-angle, east-dipping fault, thought to be an extension of the Chabot fault, separates Upper Cretaceous rocks from serpentine, rhyolite, and Knoxville shale north of Lake Temescal. A fault bounding the rhyolite on the east has been recognized in this area by Lawson (1914), Clark (1917), and Case (1963). It is presumed to be a reverse fault, with the Upper Cretaceous rocks thrust to the southwest over the younger Leona Rhyolite and the older rocks it has intruded.

Several thrust faults have been mapped northeast of the Hayward Fault, most of which dip to the southwest although some dip to the northeast (East Bay Municipal Utility District, written communication, 1960; Ham, 1952; Lawson, 1914). Ham (1952) tentatively correlated the Moraga fault (Clark, 1933) with the Cull Creek thrust fault in the Las Trampas Ridge quadrangle; correlation of the Moraga fault with part of Ham's Miller Creek thrust fault was proposed later by Case (1963). Compression late in the Tertiary, and possibly in the very early Pleistocene, may have produced the northwest-trending folds and faults (with the exception of the Hayward fault) and two subordinate sets of wrench faults.

It has been suggested (Bailey, Irwin, and Jones, 1965) that the Knoxville and younger rocks have been thrust over underlying Franciscan rocks in many parts of California. However, no evidence to either confirm or deny this thesis was found in the present area, as the volume of Franciscan and Knoxville rocks exposed is relatively small and the rocks are badly contorted; the age of the Franciscan Formation in this area is unknown; and the structure of the Franciscan and Knoxville rocks is here further complicated by the intrusion of the Leona Rhyolite and Northbrae Rhyolite and recent movement along the Hayward fault zone.

The Hayward fault zone contains the only faults in this area along which movement is known to have taken place in historic time. The fault zone apparently represents the most recent episode of deformation in this area, and appears to cut or merge with the older Chabot fault; it is not itself cut by any north- or northwest-trending cross faults. Severe earthquakes were caused by movement along faults within the Hayward fault zone in 1836 and 1868. Surface ruptures along the fault zone were reported from San Pablo to San Leandro in 1836, and from Berkeley to Warm Springs (southeast of the map area) in 1868. Therefore the entire length of the Hayward fault zone in the map area can be assumed to be active. The exact lines of the 1836 and 1868 ground rupture within this area are unknown in detail; 1868 breakage reportedly extended across the west side of the California School for the Deaf and Blind and northwestward between Prospect and Warring Streets, in Berkeley near Foothill Boulevard about a block southeast of 98th Street; and in the area indicated south of San Leandro Creek (Radbruch, 1965). Recent right-lateral offset along the fault is indicated by bends in Arroyo Viejo and Strawberry Creek. Movement along the fault has been both vertical and horizontal with the most recent movement being right lateral; that is, rocks on the northeast side of a fault within the zone have moved southeast (right) with respect to those on the southwest side.

The exact width of the zone of faulting is difficult to determine, but it is estimated to range from about 500 feet, south of Lake Temescal, to more than three-fourths of a mile, near the Oak Knoll Naval Hospital. Fault traces shown along the zone are based on a variety of evidence including the alignment of springs, topographic sags or trenches, fault scarps, offset streams, fault contacts between rocks of different age and lithology, borings showing unusual depth to rock, and extensive shearing of exposed rock. In many places the trace locations are inferred and are therefore only approximate. These traces should not be construed as indicating the only lines within the zone where movement has taken place in the past, nor are they necessarily lines where movement will take place in the future. Future movement within the Hayward fault zone may or may not follow the specific traces of faulting shown on the map.

Slow tectonic movement, or creep, is at present taking place at several locations along the Hayward fault zone, with resultant damage to manmade structures which cross the line of creep. Both the Claremont water tunnel and the drainage culvert under the University of California stadium have been damaged by this slow movement along a fault within the Hayward fault zone (Blanchard and Laverty, 1966; Bolt and Marion, 1966; Radbruch and Lennert, 1966), and creep is probably occurring along the fault zone elsewhere in the map area. Discrepancies recently noted in rechecks of survey lines crossing the zone at 98th Street and at Lincoln Avenue in Oakland may indicate right lateral movement in the fault zone of approximately 0.1 to 0.15 foot in ten years (Earl Buckingham, Supervising Civil Engineer, City of Oakland, oral communication, 1966). Cracking and offset of curbs observed in Richmond also may be the result of creep along the Hayward fault zone. Tectonic creep within the Hayward fault zone is clearly shown to the southeast, in Fremont (Bonilla, 1966; Cluff and Steinbrugge, 1966; Radbruch, Bonilla, and others, 1966). Structures which lie within or cross the Hayward fault zone not only may be damaged by sudden movement, offset, and rupture along a fault at the time of an earthquake originating in the fault zone, but also may be subject to constant strain and concomitant damage due to continual very slow movement along a fault.

[1] All map units shown in the explanation are described in the text with the exception of landslide debris (Qls), which generally consists of disturbed soil and(or) other earth material similar to that of the map unit shown surrounding the landslide on the map.

[2] Dry density (dashed underlining) expressed in lbs per cu ft; based on one sample of fresh rock unless otherwise noted. Number of samples and range of dry density and moisture content given in parentheses; (12: 106-109; 17-20%). (s) indicates sample collected at the surface. Moisture content (percent) generally higher for subsurface samples of rocks than for those collected at the surface. Rock types sampled indicated by abbreviations: cgl (conglomerate); sh (shale); ss (sandstone).

[3] Unified soil classification (letter symbol) given where applicable (Corps of Engineers, U.S. Army, 1953, "The Unified Soil Classification System": Corps of Engineers, U.S. Army, Technical Memorandum no. 3-357, vol. 1-3).

[4] The lithology and physical properties of some formations of the Monterey Group in this area vary considerably from place to place. Mapping of formations often has been based largely on stratigraphic position, rather than lithology. In this compilation an attempt has been made to mention the various rock types within each map unit, or to note places where the lithology and(or) physical properties differ from those described for the main body of the formation. However, the precise characteristics of each unit cannot be determined except by detailed field mapping, which is beyond the scope of this present compilation. Each construction site, therefore, should be carefully checked in the field, to determine the special characteristics of the rocks underlying the site.

[5] Lithology and physical properties of Hambre Sandstone in hills east of El Sobrante differ from characteristics of unit elsewhere. Much is fine-grained, firm, massive, feldspathic sandstone; slope stability and foundation conditions good, little sliding on natural slopes, stands well in cuts of 1½:1 with no slumping or washing.

[6] Parts of the unit shown as Oursan Sandstone north and east of Pinole Creek, in the north-central portion of the map, are predominantly claystone, siltstone, or interbedded claystone, siltstone, and fine sandstone. These fine-grained rocks are susceptible to sliding.

[7] The Leona Rhyolite was considered Pleistocene in age by Robinson (1953, 1956) on the basis of work in the Hayward quadrangle. He believed it to be post-Pliocene because it was only slightly deformed in the area studied. Previous workers (Lawson, 1914; Clark, 1917), on the other hand, reported that the rhyolite had been much affected by faulting, and recent work by the authors in the map area indicates much faulting and deformation of the rhyolite. Lawson tentatively dated the Leona Rhyolite as late Tertiary, probably Pliocene; Clark thought it was probably Pliocene or older. Its age is considered Pliocene(?) in this report.

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*For detailed discussion of stratigraphy of these units see Case (1963).

Landslide debris*

*Landslide debris shown on the map was observable at the time of the study from which the data were compiled; however, not ever landslide in the area is shown on the map. therefore, although landslide debris exists (unless it has since been removed by construction activity) at every point where it is shown on the map, it does not follow that there are no landslides elsewhere on the map